

**A new way
to a sounder**

N/C

investment



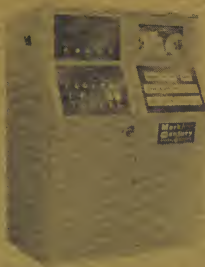
Mark
Century

41 questions you should ask when evaluating numerical control

Many machine builders offer a choice of numerical controls with their product. Each control can cycle the machine and may produce parts of comparable quality.

But how well the controls meet other important requirements proves which control is best for you. Performance, reliability, application flexibility, maintenance, service, and computer software . . . these determine how much profit your equipment investment will yield. They are what you should evaluate—in the light of your individual needs.

Here then, are forty-one questions—the answers to which will help you evaluate and compare makes of numerical control.



Mark Century

PERFORMANCE

0.0001

vs
0.001

Q. Does the control use the latest digital techniques?

A. With transistorized circuitry, it is now possible to improve both the speed and accuracy of machine-tool controls. And it is generally agreed that the accuracy and performance of digital circuitry are far superior to analog.

General Electric's Mark Century* control logic is completely digital, capitalizing on the inherent reliability of solid-state devices. This helps assure long control life and accurate performance.

Q. Does the system accept input commands to 0.0001 inch?

A. General Electric Mark Century* controls accept data to a resolution of 0.0001 inch. This allows the machinery builder to offer the best possible accuracy with his machine. Other control systems range from 0.001 to 0.0002 inch. Under certain conditions due to computational roundoffs, etc., the wider resolutions can result in added tolerance variations on the machine part.

Q. Is this a closed-loop servo system?

A. In the numerical control of a machine tool it is important to have a feedback loop to make certain that the equipment is always under positive, accurate control during the entire operation. Some controls rely on the accuracy of the drive motors alone to obtain system and part accuracy.

Mark Century controls are closed loop, to give you positive, higher-accuracy control of the entire cycle. The high-accuracy feedback device gives long-term accuracy to the system.

Q. Has the control system builder engineered the servo drives to get maximum performance from the machine?

A. The servo system is one of the most important elements in a numerically-controlled machine. Yet, you can't see it. If improperly applied, the machine will overshoot and suffer excessive shock loading from the control equipment. To compensate for

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shock and overshoot, many controls use programmed acceleration and deceleration which mean increased programming time and more machine cycle time. This increased cycle time means less production from your machine and less profit for you.

The Mark Century control is unique in its servo design. Mark Century control has little or no overshoot under normal operating modes and operates the machine within its mechanical limitations without programmed acceleration or deceleration. This means less machine shock, less machine maintenance, minimum control adjustment, and greatly improved cycle time. Because of its unique servo design. Mark Century control reduces machining time and provides higher quality parts with less equipment maintenance.

Q: Is the tape reader adequate for the application?

A: The tape reader can restrict machine speed under some circumstances. Make sure the control you buy has the best reader for your application. Mark Century controls are available with one of three readers: mechanical, photo-electric, or magnetic tape. The reader supplied is matched to the machine requirements.

Q. Has this control and servo system previously been applied to this particular machine type?

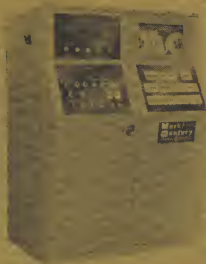
A. Reliability is a function of experience and meticulous attention to detail. Many years of experience show that the servo mechanism and the associated control servo loop is the most critical part of the numerical control.

The Mark Century control has been applied to virtually every type of machine using all types of servo drives. Whether the servo be hydraulic, d-c motor, or electric clutch, General Electric can meet your needs with excellence proven by many hundreds of machines in continuous production.

PERFORMANCE



RELIABILITY



Mark Century

RELIABILITY



Q. How much experience does the control manufacturer have?

A. There are over 20 significant manufacturers of numerical control. Some have years of experience. Some are new to the field. The extent of the control manufacturer's experience will have considerable effect on the control's performance and the performance of your entire machine.

General Electric has more than 50 years' experience in the electrification of machine tools. The Mark Century control has been applied to all major machines including: drills, lathes, turret lathes, boring mills, milling machines, drafting machines, and multi-purpose equipment. No other control manufacturer matches this coverage.

Q. Is the control industrially rugged?

A. The life and long-term reliability of a control system can be affected by the package in which it is housed. If the enclosure design does not offer sufficient protection, the value of your investment decreases prematurely and you'll have continual problems over the life of the control and machine.

Mark Century controls are designed to withstand cross-country shipment, in-plant moves, and the wear and tear of machine-shop conditions. Sheet metal is heavy, special bracing adds rigidity, and weld joints mean permanent alignment of panels and doors.

Q. Do operators' devices used throughout the control meet industrial quality?

A. N/C machine tools operate in an atmosphere normally contaminated with metallic particles, oil, and coolant mists. Even oil from an operator's hands can eventually enter light-duty switching devices and cause failure.

General Electric uses industrial quality push-buttons and components throughout Mark Century controls.

RELIABILITY

Q. Is the cabinet sealed from normal shop contamination?

A. Solid-state circuitry and electronic components are generally more reliable over an extended period of time when they are housed in a clean environment and when extreme temperature ranges are avoided. Normal shop operating conditions do not meet this requirement.

General Electric's experience in packaging for these conditions has resulted in a gasketed cabinet that is sealed and air conditioned to maintain component operation at a high level of reliability under a wide variety of shop environmental conditions.

Q. Is the logic circuitry completely solid state?

A. The term solid state, without adequate definition, can be misleading. It's an outgrowth of transistors in control circuitry, and means an absence of relays, stepping switches, vacuum tubes, etc.

Solid-state circuitry has inherent reliability, fast operating speed, and small size. Controls using relays or reed switches in analog circuits as a substitute for the latest digital techniques are subject to wear, mechanical failure, and shorter life.

Mark Century controls are all solid-state, for long life and dependable maintenance-free operation. Relays are only used to isolate the logic circuitry.

Q. Are printed circuit boards used throughout?

A. With transistors and computer-type circuitry, controls can be built in modular form—with functions isolated. If circuit boards are used throughout the control, maintenance is substantially simplified.

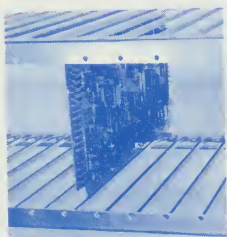
Mark Century controls use circuit boards throughout, except for power supplies and machine magnetics.

Some numerical controls use circuit boards in only one section, such as data read-in. The remainder is relays or vacuum tubes.



Mark Century

RELIABILITY



Q. Is the printed circuit board made of the most stable material?

A. Under normal operating conditions, electronic components generate enough localized heat to warp many types of printed circuit board materials. This can cause short circuiting . . . affecting reliability of the entire system.

Common materials for boards are pressed fiber, pressed paper, or glass-epoxy laminate. Intensive tests in our laboratories have shown the glass-epoxy laminate to be most stable. Therefore, Mark Century N/C uses it for all circuit boards to insure long-term stability and reliability.

Q. Are circuit boards adequately supported?

A. For additional board protection, each Mark Century circuit board is carried in a channel track both at top and bottom over its entire length. This method of support improves connector alignment and prevents board damage.

Q. Do board connectors establish positive contact?

A. Board connectors can significantly affect system reliability. Some N/C manufacturers use edge-card-type connectors which slip into crimped receptacle sockets. The connectors wear readily because of their minimum effective contact area.

Mark Century connectors—with a broader contact area—insure excellent positive contact and maximum reliability.

Q. Are wire wrapped connection techniques employed?

A. Connection techniques have a direct relationship with control system reliability. Poor electrical connections are major contributors to system failure in any circuitry. The most popular wiring techniques used in N/C systems today are soldering and wire-wrapping.

Research and field operating experience over a long period of time have shown that wire-wrapped connections are virtually trouble-free, whereas im-

perfect solder joints tend to fail under vibration and shock conditions.

Where practical, General Electric uses the wire-wrapping technique in all control systems.

Q: How wide a choice of machine types and makes is available with this control?

A: There are many real benefits wherever standardization can be achieved in shop equipment . . . without limiting capability. Since many control makes are available only with a limited number of machines, this should be considered with future numerical control machine purchases in mind.

General Electric numerical controls are in use with machine tools built by over 50 manufacturers, and are furnished as standard equipment with a full range of machine types. All Mark Century n/c systems also offer substantial similarities in design and construction which simplifies personnel training, maintenance, and operation.

Q. Does it meet NMTBA standards?

A. To promote personnel safety, uninterrupted production, long equipment life, and low maintenance cost, the National Machine Tool Builder's Association (NMTBA) has established standards for electrical equipment on machine tools.

General Electric Mark Century numerical control meets all applicable portions of NMTBA standards.

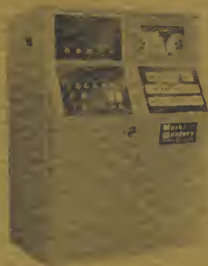
Q. Is the input tape standard EIA?

A. The Aerospace Industries Assn. (AIA) and the Electronics Industries Assn. (EIA)—based on considerable research—have written a standard for N/C data input media. EIA-RS-227 is their guide to the coordination of equipment, and describes a tape that satisfies requirements of present-day N/C equipment.

All General Electric N/C equipment accepts tape conforming to this standard.

RELIABILITY

APPLICATION FLEXIBILITY



Mark Century

APPLICATION FLEXIBILITY



Q. Is input code standard EIA?

A. EIA also has issued a standard for character codes for N/C tape: EIA-RS-244. It is a guide for N/C design coordination to minimize the number of tape sizes and codes used and the variety of tape preparation equipment required by N/C users.

All General Electric N/C equipment accepts tape codes which conform to this standard. Although most major N/C system builders adhere to this standard, several systems are available which do not.

Q. Does input data require special processing?

A. To some extent, any input data—since it is in coded form—requires some processing. It is normally necessary to take the raw data from its initial format and rearrange it in another form to manipulate the machine tool in the desired sequence.

It is also necessary to translate this properly arranged information into some form of code which is acceptable to the machine and control system. EIA standard coding allows N/C tapes to be processed through most standard tape punching and tape operated typewriters.

All machines with Mark Century controls accept tapes prepared on standard business machines.

Q. Is the input media compatible with expected future requirements?

A. As recently as four years ago, there were 37 different ways of handling data input. They ranged from a seven-inch steel tape to the present EIA one-inch punched tape.

Users who purchase equipment having a variety of controls with a variety of data input methods find that operating expenses, training of personnel, and maintenance complications soon become prohibitive. Therefore, it is wise to consider your future N/C need in making any control determination.

All Mark Century controls—positioning and contouring for metalworking and nonmetalworking applications—meet industry standards for data input. With Mark Century control you are protected from possible obsolescence of special control designs.

Q. Is the control system arranged for easy access to all areas for maintenance?

A. Ease of maintenance is a vital consideration in any industrial equipment.

Mark Century controls are designed with all service areas completely accessible. For easier maintenance, circuit boards are mounted in swing-out racks and have individual handles for easy removal and replacement. The boards are arranged functionally and have connectors for condition-indicator checking. Test jacks are built into the control circuitry. In addition, power devices are conveniently located—and protected—in accordance with NMTBA standards.

Q. Is the standard input form of binary coded decimal numbering (BCD) used in the computing portion of the control?

A. The Electronic Industries Association has established a standard for N/C data input coding, called binary coded decimal (BCD). This easily understood coding arrangement can also simplify trouble shooting.

All control systems which conform to the standard must accept this coding through their tape reader. After accepting the input data in this form, most systems translate it into another coding form as a short-cut-method of developing machine commands.

By using another code form, data in the logic section of the control is disbursed throughout the boards in no logical arrangement. Although manipulation of mathematical data is the basic function of the control, the added translation step greatly increases the probability of failure in the interpolation process.

Mark Century controls use BCD coding throughout the computing portion. Each circuit board represents a specific computer function. The boards are arranged in easily identifiable groups which represent decimal numbers in their logical order.

MAINTENANCE





Mark 100 Century

MAINTENANCE



Q. Are check tapes provided for automatically checking the control circuitry?

A. There is a distinction between test tapes and check tapes. When a machine tool is ordered with numerical control, the specifications usually stipulate some type of acceptance test runs, such as machining metal in various modes of operation. Test tapes—which perform this function—are used for testing the **total accuracy of the machine/control complex** for acceptance and recertification. Responsibility for providing test tapes normally falls to either the user or the machine tool builder.

Check tapes are designed to check control circuitry to isolate problem areas. Check tapes—when available—are provided by the control system manufacturer. Check-tape tests automatically pinpoint trouble areas in the logic section of the control. They greatly reduce the need for technical troubleshooting equipment.

General Electric furnishes a set of check tapes with every control. A short tape rapidly exercises the entire logic section. Successful running of this tape will ensure that the control logic is operating accurately in all areas. Since the tape exercises the control systematically, section by section, failure of the tape to complete its cycle will identify a section of the control in which the malfunction occurs.

To pinpoint the faulty board, maintenance personnel can then use a second tape which is designed to test the faulty section, board by board. This tape stops when the faulty board is reached . . . identifying it. Replacing the faulty board and re-running the first check tape ensures that the control is operating satisfactorily in all areas.

Q. Can numbers in the logic circuit boards be easily read directly from the boards by maintenance personnel?

A. For troubleshooting, it is sometimes desirable to introduce numbers into each motion and feed-rate register, and to visually check the registers

to determine if the proper numbers have been recorded.

General Electric arranges the counter boards in logical decimal order, which can be easily read as decimal numbers from the back of the circuit board racks. This feature—not available on most systems—is accomplished through use of readout lights. The lights are arranged on auxiliary boards which can be plugged into the exposed end of the counter boards. They display the number currently registered in each board.

Q. Are cables plug-in type for easier installation wiring?

A. Interconnections between machine, control, and peripheral equipment are relatively complex. After initial installation, most machines are later moved within a shop because of reorganizations, expansions, etc. Reconnecting after a move can take considerable time.

Mark Century controls are provided with plug-in inter-connecting cables. The equipment can be moved with a minimum of reconnecting time.

Q. How many different types of circuit boards are used in the control?

A. Standardizing printed circuit boards in control equipment minimizes the number of types and sizes. This reduces the cost of spare parts, cuts continuing support cost of the equipment, and makes maintenance far easier.

Mark Century control does all this. What's more, with Mark Century controls, most circuit boards are interchangeable between contouring and positioning controls—whether applied to boring or profile milling machines. In fact, Mark Century control can be supported with approximately half the spare parts stock required by some other makes.

MAINTENANCE



SERVICE



Mark Century

SERVICE



Q. Does the control system manufacturer have a regularly scheduled maintenance training school for your people?

A. Numerical control—a true electronic system—requires technically trained personnel to ensure satisfactory performance at all times. Although reliability of present day solid-state control systems is excellent, knowledgeable maintenance technicians are still needed for preventive maintenance.

General Electric has the most extensive training-school program in the industry. Regularly scheduled courses are provided throughout the year for all types of G-E control. In the past six years over 1000 people have successfully completed these courses.

Before attending the school, General Electric prepares the students in elementary, solid-state logic circuitry by using the newest teaching method known as programmed instruction.

Q. Does the control manufacturer provide local service?

A. Your own maintenance personnel should be backed up by the control manufacturer to provide fast, competent service when needed.

General Electric has a worldwide network of expert, factory-trained, numerical control specialists who are all electronic engineers. It is the largest service staff for N/C maintained by any manufacturer. The immediate availability of these specialists to support your own service personnel is an additional assurance of satisfactory performance from your numerically controlled machine tools.

Q. If you do not have a qualified N/C maintenance technician, does the control builder offer a maintenance contract?

A. Many users of N/C equipment must either hire or train a maintenance technician to support their first purchase of numerical control equipment. During the period of recruiting or training, General Electric offers a complete maintenance contract

through any service office. This contract—separate from the normal service policy—covers preventive and regular calls from G-E service personnel to maintain the equipment in top operating condition.

Q. Are complete diagrams and adequate service manuals available?

A. Every technical serviceman in your plant who is responsible for N/C service needs complete wiring diagrams, service manuals, and operating theory. General Electric supplies the most complete diagrams and service manuals for N/C available in the industry. Based on feedback from our own many N/C installations within General Electric and from many customers, we have compiled service manuals and instruction books which are easy to use and practical for the broad spectrum of users.

Q. Are spare parts readily available?

A. There is a relatively long lead time for some control systems parts, just as there is for some machine tool parts. A breakdown or malfunction of the control can cost many dollars in lost production time . . . if the equipment must wait for a needed part.

General Electric recommends that users maintain an inventory (we furnish a list of suggested parts), part of which is purchased with the original equipment. Also, a supply of spare parts is maintained in key service locations throughout the United States. These are available to you when they are needed in a hurry. Because of the great commonality among all G-E control systems, your spare parts inventory can be kept to a minimum.

Q. Is an APT postprocessor available?

A. If you intend to use computer-aided part programs, you must have a postprocessor to convert the output into a coded tape which is acceptable to the machine and control. This is the function of the postprocessor.

SERVICE

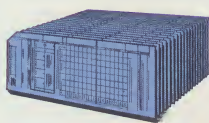


COMPUTER SOFTWARE



Mark Century

COMPUTER SOFTWARE



To support computer-aided part programming, General Electric has developed the GECENT postprocessor for the APT computer program. It is available to all APT participants—regardless of machine—for use with Mark Century control.

Q. Is the postprocessor compatible with the latest version of APT?

A. APT III, the latest version of APT, is a program designed to keep abreast of advancing technologies. But for APT III to be used effectively, the postprocessor must be dynamic and able to grow with it.

The Mark Century GECENT postprocessor is the only postprocessor specifically designed to match APT III, and is continually being upgraded to meet rapidly changing technology.

Q. Is the postprocessor modularized for universal application?

A. Most control builders offer individual postprocessors for each machine. This makes updating, correcting, changing, and extending very expensive. Cataloging and storing also become increasingly difficult as more and more N/C machines are added to your plant.

The GECENT postprocessor is a modular postprocessor that can be used with all machines. This reduces the number of post processors required to handle a variety of machine tools. Also, training costs are reduced since a computer installation needs to train part programmers in only one postprocessor . . . not a separate program for each machine.

Q. Has the postprocessor been field tested and proven?

A. The GECENT postprocessor is one of the most reliable available today. It has been proved in

constant usage in many plants with a wide range of machine tools and a great variety and complexity of parts. It is written in FORTRAN, the computer language used for most types of large computers.

Q. Is complete documentation available?

A. Documentation of a computer program is a complete description of what is in it and how to use it. A postprocessor is no better than its documentation. If the personnel using it do not understand it, the postprocessor cannot be effective.

The GECENT postprocessor is the most completely documented postprocessor available, and conforms to the documentation standards set for the APT Long Range Project by IIT Research Institute.

Q. How does the postprocessor affect the cost of computer programming?

A. The cost of computer-assist programming can vary widely with the type of postprocessor in use, because of the computer time required.

For example, with the GECENT postprocessor up to 10 parts can be programmed in one computer load, or the same part can be programmed for several machines. Thus, significant cost and time savings can be achieved and production flexibility improved.

Q. Does the postprocessor have self-checking routines?

A. The GECENT postprocessor contains an elaborate diagnostic system—over 500 diagnostic statements—as a self-checking device against errors in part programming and for other causes of failure. It is designed to make standard assumptions where the part programmer has omitted information, so post-processing can continue.

This is particularly important where there is access to the computer only once a day. Failure of a part program to run successfully means missed schedules, idle machines, and high programming costs.

COMPUTER SOFTWARE





Mark Century

COMPUTER SOFTWARE

Q. Are other computer programs and postprocessors available?

A. Many companies have installed small or medium sized computers and ask if programs similar to APT are available to them. Definitely yes. General Electric has implemented ADAPT, a smaller version of APT, on its GE-225 and GE-415 computers. It has also developed a generalized, modular postprocessor called GEDAPT for the ADAPT program. Because of its modular construction and the fact that it is written in FORTRAN it can also be used with computers of other manufacturers as well for their versions of the ADAPT program.

General Electric also has the PRONTO program for work on positioning machines. In addition, special assistance is available for the application of computers to a wide range of manufacturing needs.

You may have further questions—on numerical control in general or Mark Century control in particular. If so, contact your nearby General Electric Industrial Equipment Sales Representative, or write General Electric Company, Specialty Control Department, Waynesboro, Virginia.



Specialty Control Department, Waynesboro, Virginia

EVALUATION WORKSHEET

**A new way
to a sounder
N/C
investment**

PERFORMANCE

Weight

G-E MARK
CENTURY N/C

VALUE

AD-
JUSTED
VALUE

VALUE

AD-
JUSTED
VALUE

VALUE

AD-
JUSTED
VALUE

VALUE

AD-
JUSTED
VALUE

Does the control use the latest digital techniques?

7

Does the system accept input commands to 0.0001 inch?

3

Is this a closed-loop servo system?

5

Has the control-system builder engineered the servo drives to get maximum performance from the machine?

8

Is the tape reader adequate for the application?

2

Subtotal

Category Multiplier _____

RELIABILITY

Weight

G-E MARK
CENTURY N/C

VALUE

AD-
JUSTED
VALUE

VALUE

AD-
JUSTED
VALUE

VALUE

AD-
JUSTED
VALUE

VALUE

AD-
JUSTED
VALUE

Has this control and servo system previously been applied to this particular machine type?

3

How much experience does the control manufacturer have?

4

Is the control industrially rugged?

2

Do operators' devices used throughout the control meet industrial quality?

1

Is the cabinet sealed from normal shop contamination?

2

Is the logic circuitry completely solid state?

2

Are printed circuit boards used throughout?

2

Is the printed circuit board made of the most stable material?

1

Are circuit boards adequately supported?

1

Do board connectors establish positive contact?

1

Are wire wrapped connection techniques employed?

1

Subtotal

Category Multiplier _____

APPLICATION FLEXIBILITY

How wide a choice of machine types and makes is available with this control?

Does it meet NMTBA standards?

Is the input tape standard EIA?

Is input code standard EIA?

Does input data require special processing?

Is the input media compatible with expected future requirements?

Subtotal

Category Multiplier_____

MAINTENANCE

Is the control system arranged for easy access to all areas for maintenance?

Is the standard input form of binary coded decimal numbering (BCD) used in the computing portion of the control?

Are check tapes provided for automatically checking the control circuitry?

Can numbers in the logic circuit boards be easily read directly from the boards by maintenance personnel?

Are cables plug-in type for easier installation wiring?

Subtotal

Category Multiplier_____

[illegible]

[illegible]

Category Multiplier_____

[illegible]

Category Multiplier_____

GRAND TOTAL

How to use

This convenient worksheet will help you evaluate which numerical control system is best suited to your needs.

Each of the 41 criteria in the six categories discussed in our companion evaluation booklet, *A New Way to a Sounder N/C Investment* (G-E publication GED-5311), is listed here. Space is provided alongside these criteria so you can compare G-E Mark Century* N/C and up to three other brands against the criteria listed. Facts on Mark Century N/C that are needed for the worksheet are assembled in the companion evaluation booklet.

Follow these simple steps to use the worksheet:

1. To begin, determine the relative importance of each of the six categories (performance, reliability, etc.). Making the value of all six categories total 100, assign to each category that portion of 100 that best reflects the category's importance to you (e.g. Performance, 30; Reliability, 20; Application Flexibility, 20; Maintenance, 15; Service, 10; Computer software, 5). Place these numbers in the blanks labelled "category multiplier" at the bottom of each category.
2. In the column marked "weight", weight factors have been suggested for each criterion. If you feel the weighting should be different for your application, assign a new value in the space provided.
3. Rate each control in the "Value" columns for the criteria listed. A scale of 0, 1, 2, and 3 is suggested with zero denoting the control that does not meet the criterion and three denoting the highest rating. Multiply these values by the weight factor and enter the result in the "Adjusted-Value" columns.
4. When all criteria have been considered, (there's room where you can include some of your own) add the figures in the "Adjusted-Value" columns and place the results in the subtotal blocks. Multiply these subtotals by their category multipliers and write the answers beneath the subtotal.
5. When all categories have been completed, combine the subtotals for each control and place these numbers in the "Grand total" boxes. The results will give a good indication of what control is best for you.

The value of your evaluation is only as good as the accuracy of the information used. Be sure up-to-date, accurate information is used for each control system that is considered.

For more information on General Electric numerical control, contact your nearby G-E Industrial Sales Representative, or write to General Electric Co., Waynesboro, Virginia. Additional copies of this worksheet are available from General Electric Co., Publication and Film Distribution, Schenectady, N. Y. Ask for GED-5312.

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Specialty Control Department, Waynesboro, Virginia